Simulation and Analysis of model for evolution of monogamy

Origin paper: The evolution of monogamy in response to partner scarcity

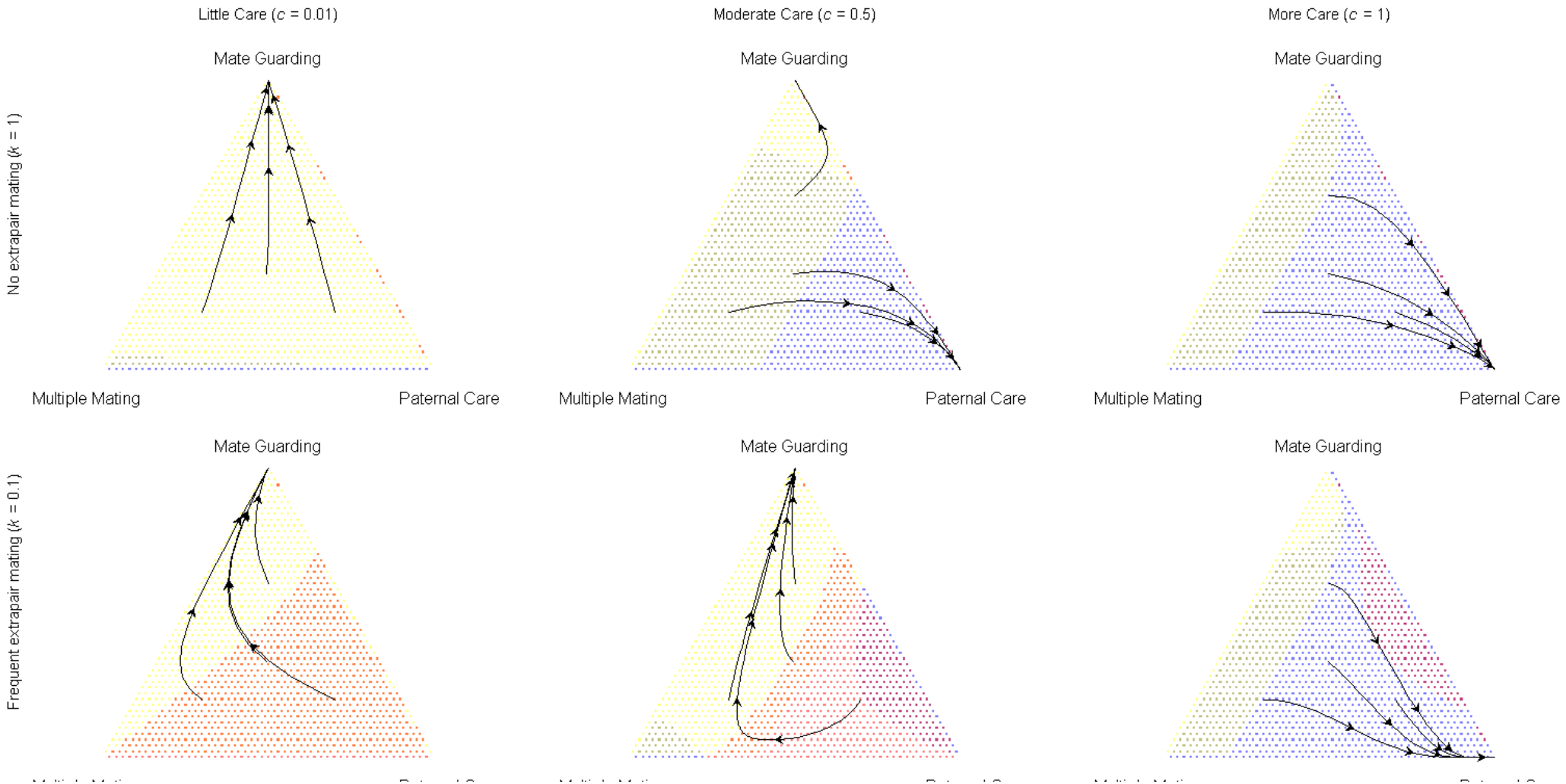
Summary of paper

- Many people claim that Monogamy is the result the parternal care(PC) because female select men who have more ability to take care of them and baby.
- This is based on axiom that female have right to select partner.
- But this stragy have vulnerbility to cuckload by Multiple Mating(MM).
- So, Male Guarding(MG) evolue first for prohibiting access to their female by MM.

Simulation

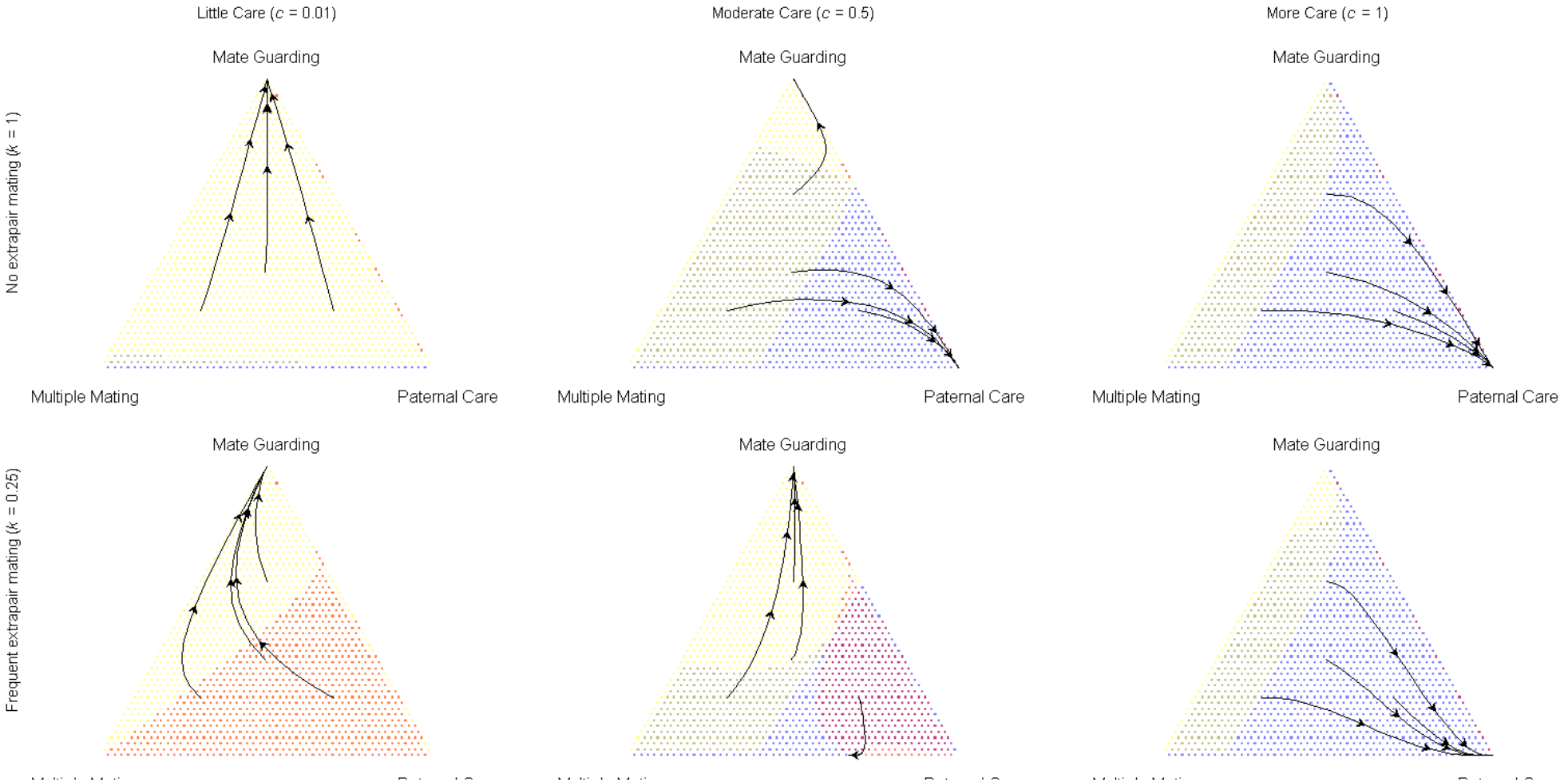
- I tried to change 3 variable u, k and y, which u is probability of men's survive, k is the willingness of females to engage in extra-pair mating and y is sex ratio.
- I tried to change u as 0.5 and 0.2 which is lower than 0.9 in paper.
- I use k as 0.1(paper) and 0.25, which the former is related to one survey and 0.25 is related to proportion of genes.
- I initialize sex ratio as not only 2/3(paper) but also 5/6, which the letter is related to Korea.

Simulation



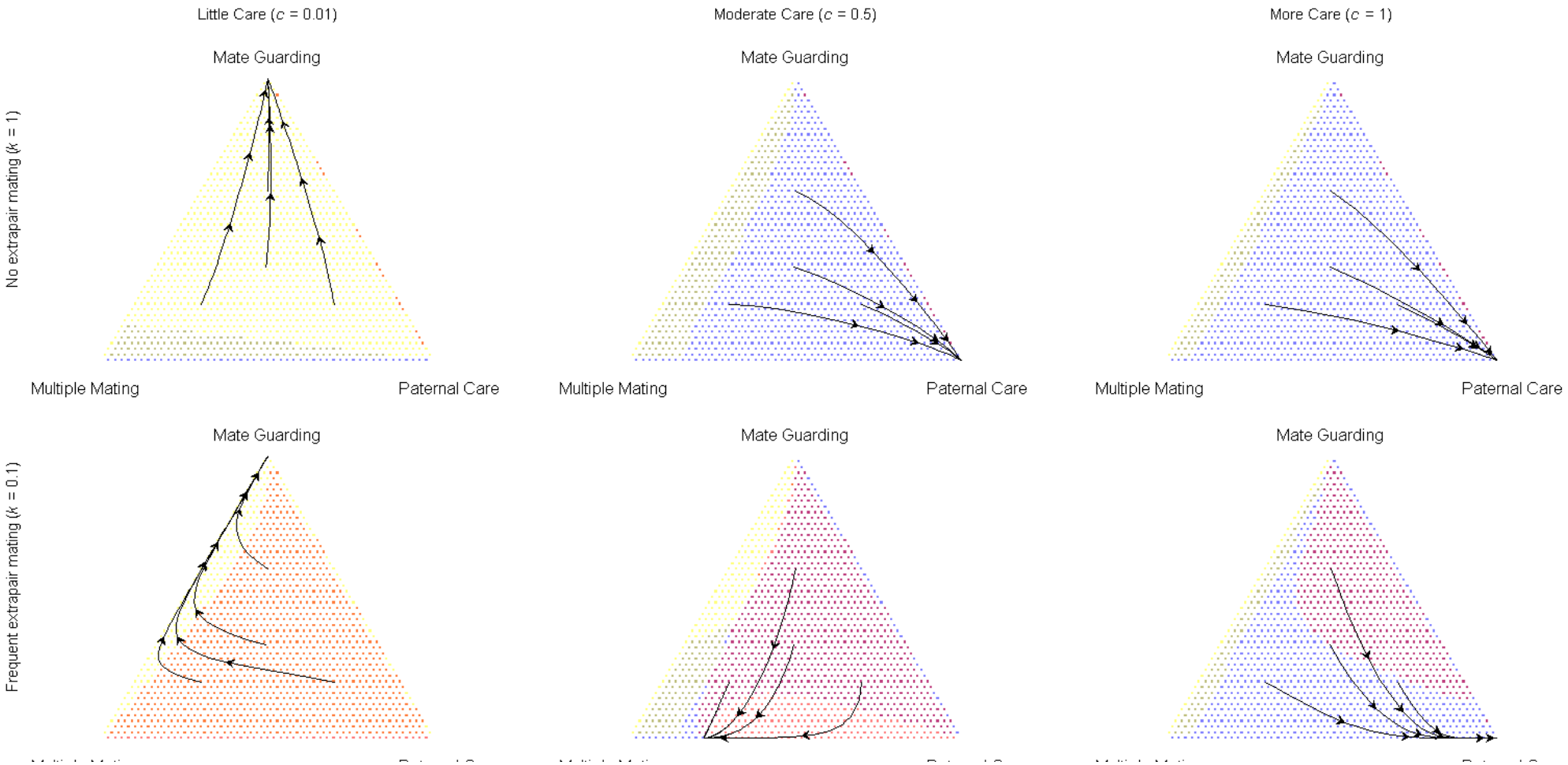
u=0.5, k=0.1, Men's biased(2/3)

Simulation



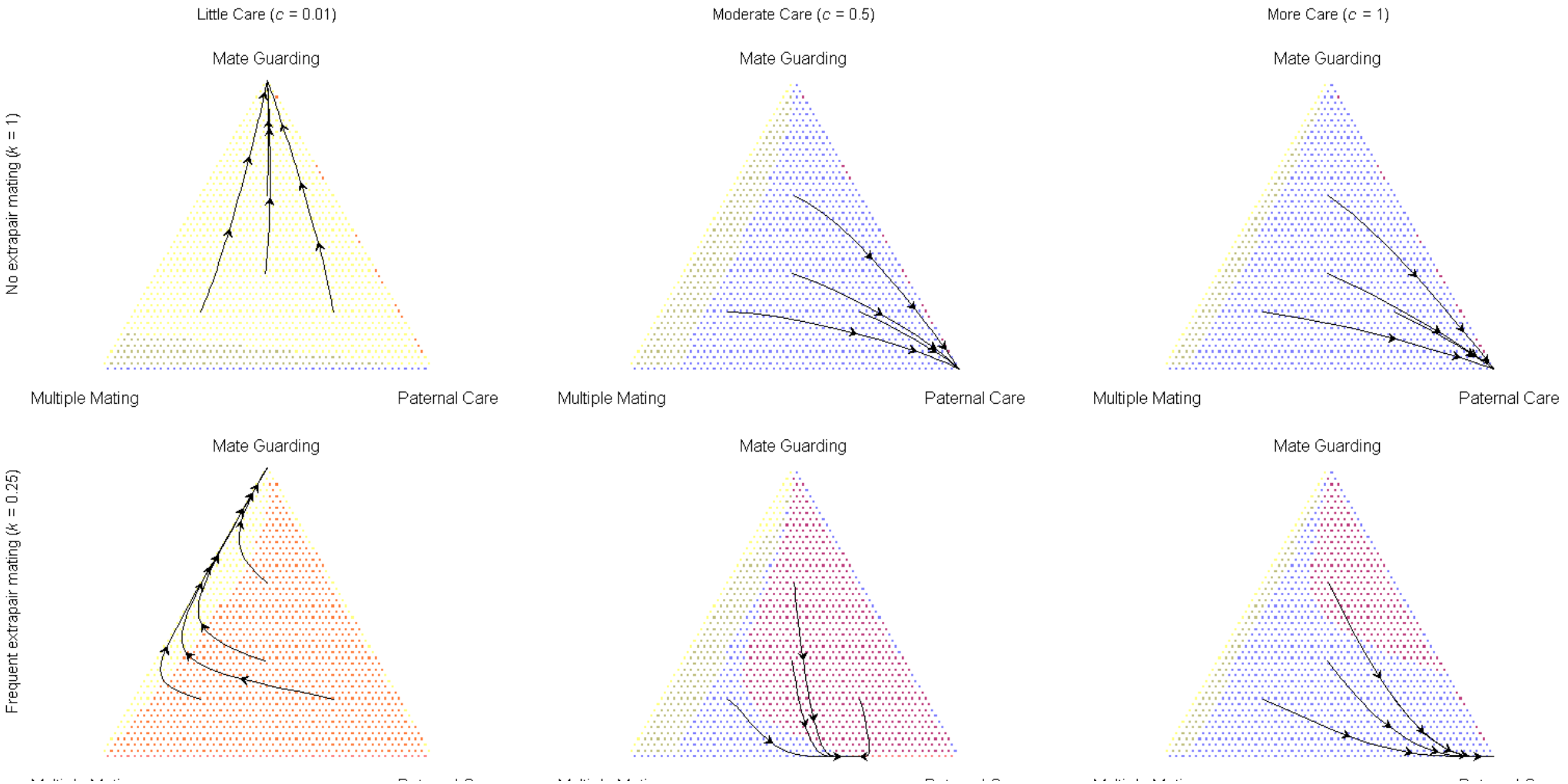
u=0.5, k=0.25, Men's biased(2/3)

Simulation



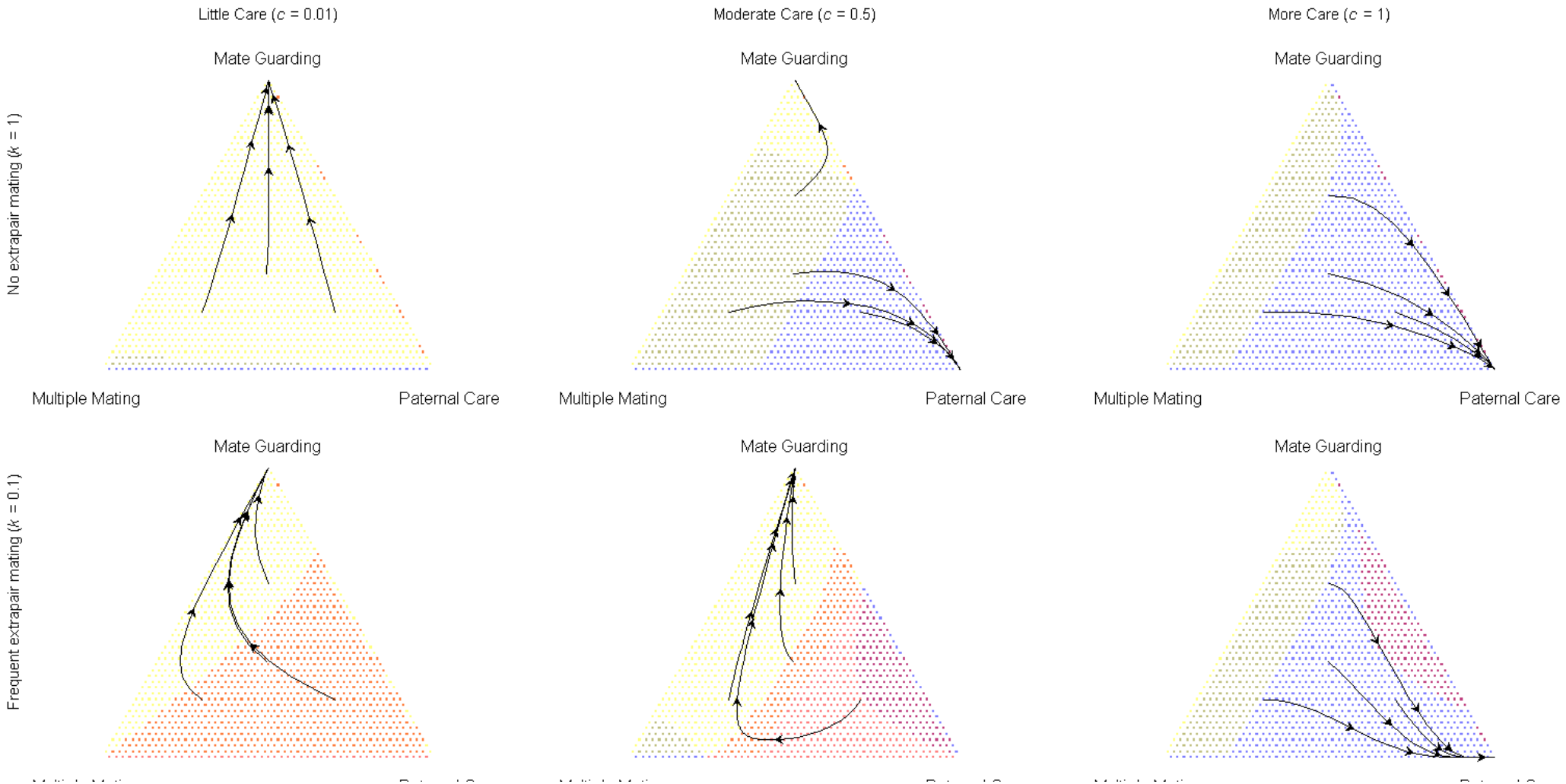
u=0.2, k=0.1, Men's biased(2/3)

Simulation



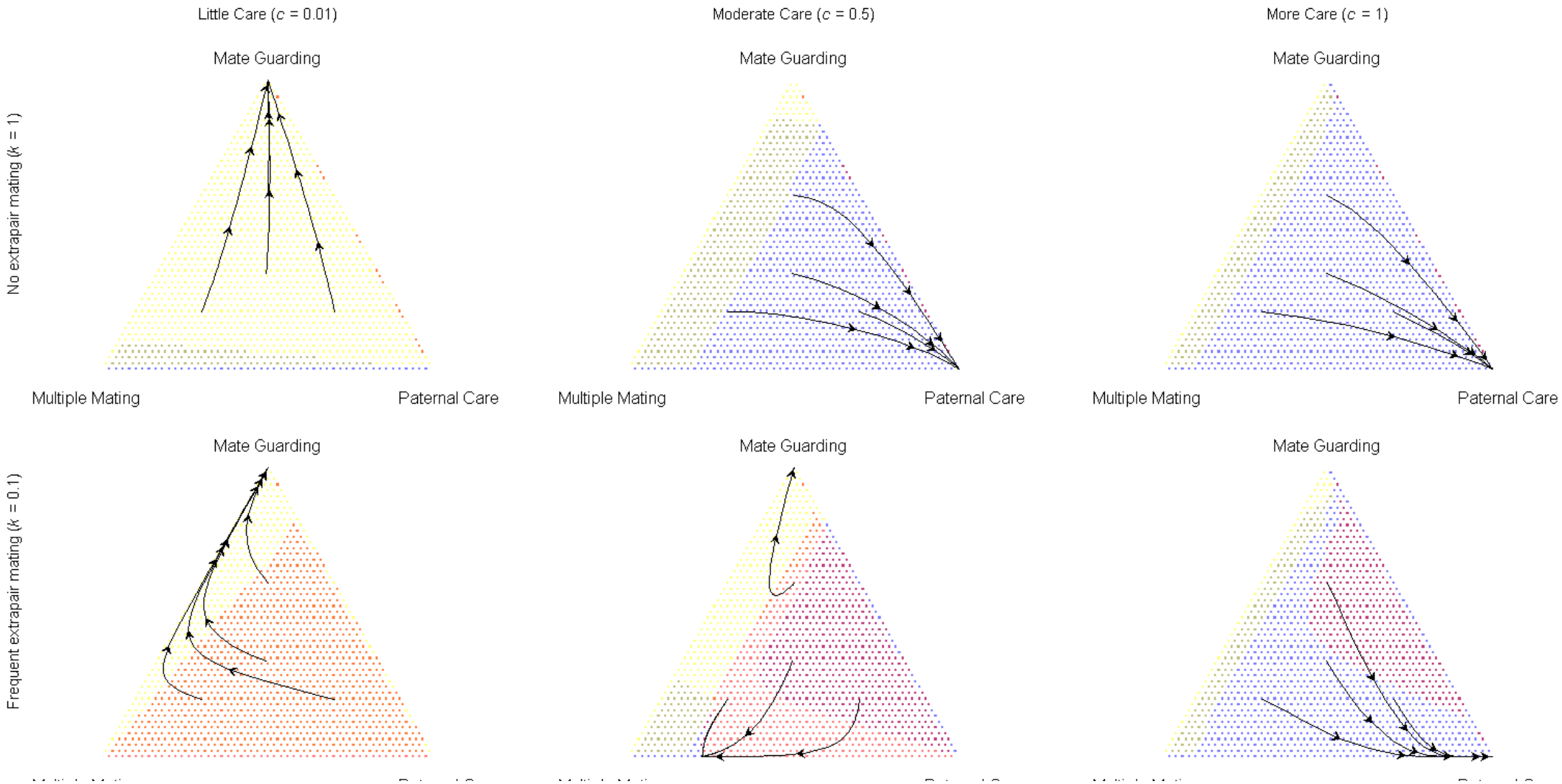
u=0.2, k=0.25, Men's biased(2/3)

Simulation



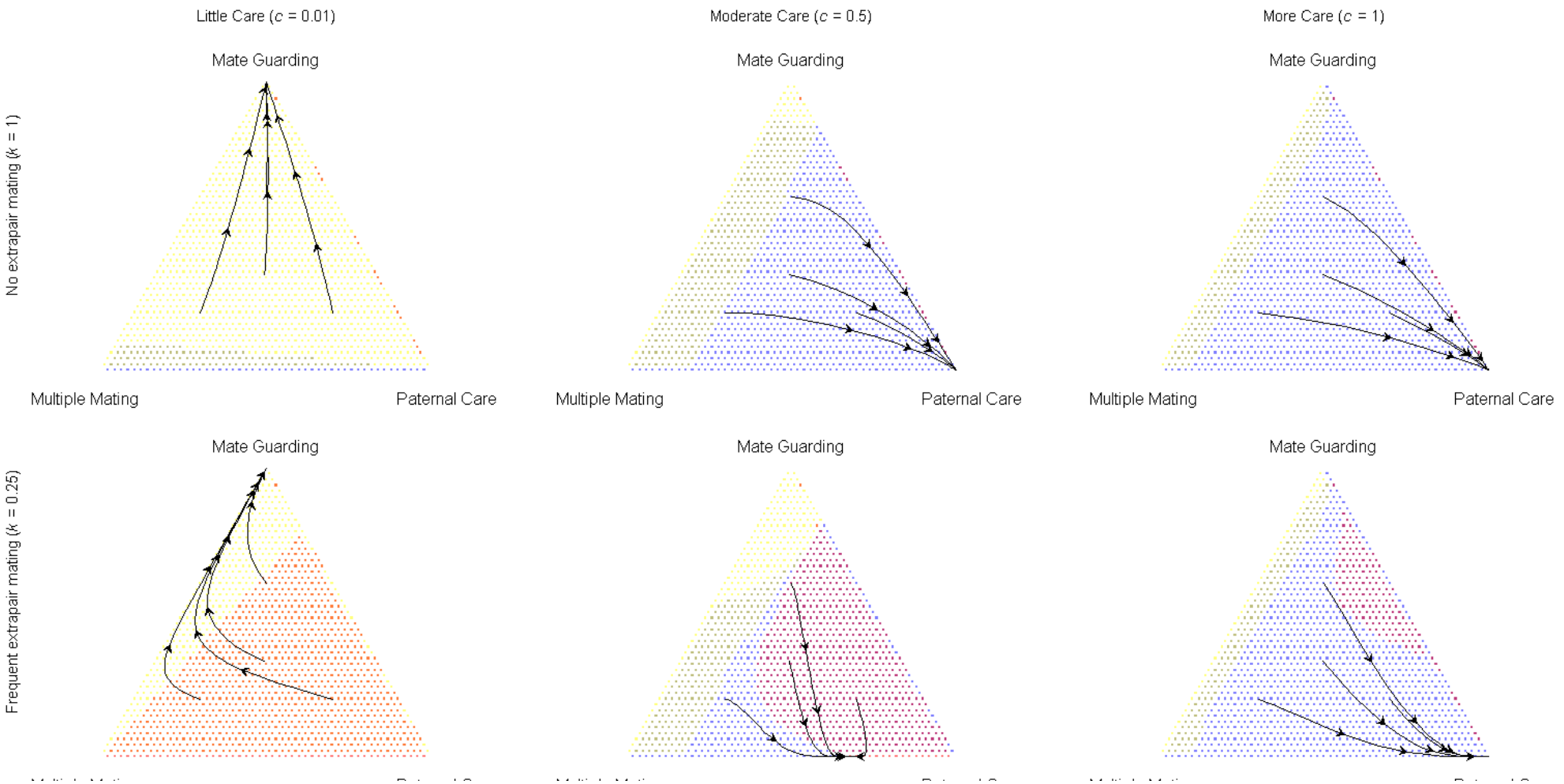
u=0.5, k=0.1, Men's biased(5/6)

Simulation



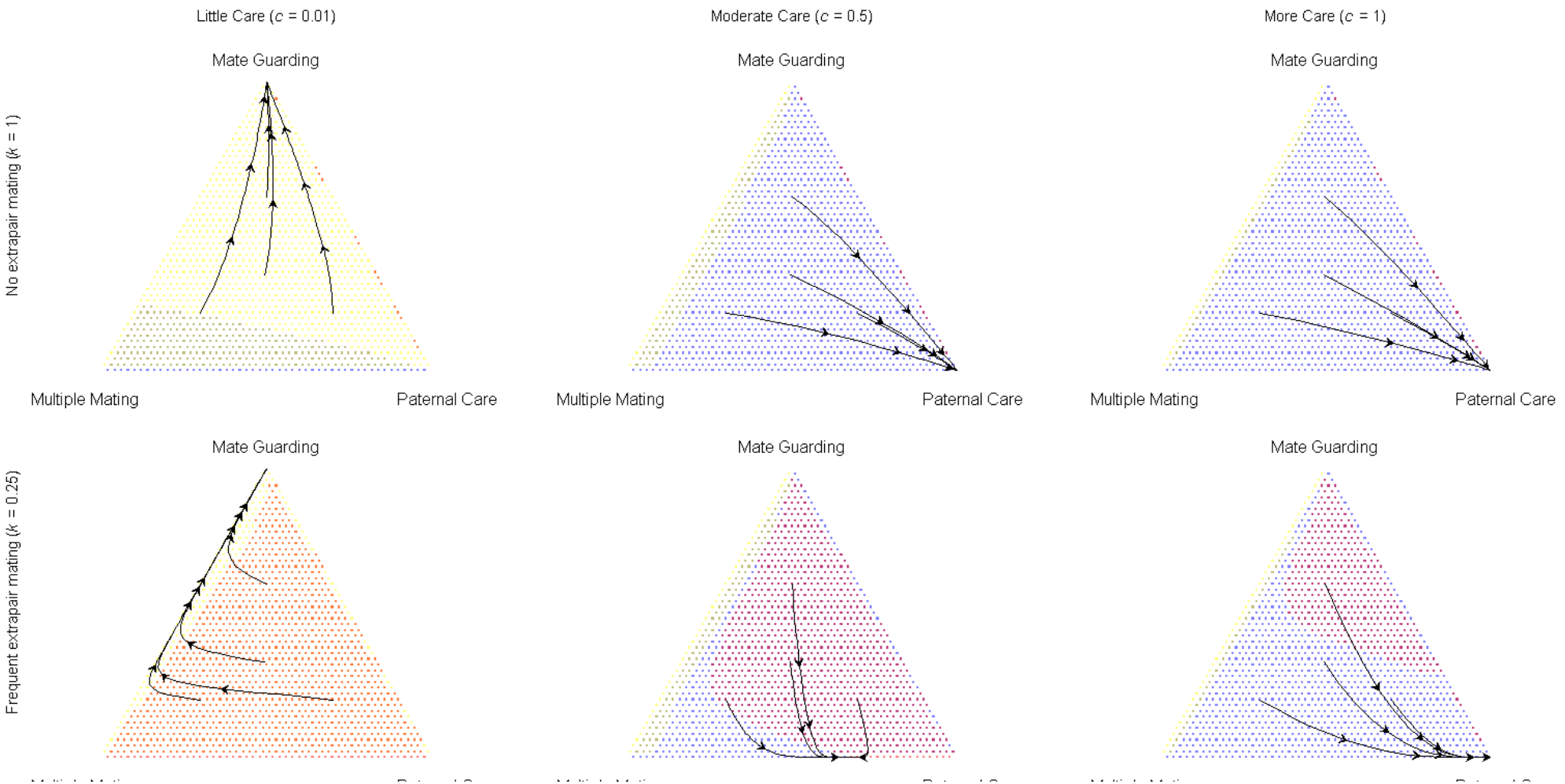
u=0.2, k=0.1, Men's biased(5/6)

Simulation



u=0.5, k=0.25, Men's biased(5/6)

Simulation



u=0.2, k=0.25, Men's biased(5/6)

Analysis

- The Stragy is determined by the fitness function.
- W_p, W_m, W_G is fitness function of PC, MM, MG.
- $W_p = \sum_{k=0}^{\infty}(1+c)u^k y_k(1-h_k)$
- $W_m = \sum_{k=0}^{\infty} u^k(y_k + (1+c)\, h_k \frac{y_k p_k}{1-p_k-q_k})$
- $W_G = \frac{y_0}{1-u} + \sum_{k=1}^{\infty} \frac{u^k y_k}{1-u} \prod_{j=1}^{k-1}(1-y_j)$
- p_k is relative ratio of PC in time k, q_k is one of MG and h_k is probability of cuckload in time k.

Analysis

- $W_p - W_M = \sum_{k=0}^{\infty} u^k \left\{(1+c)y_k(1-h_k) - y_k - (1+c)y_k h_k \frac{p_k}{1-p_k-q_k})\right\}$

$$= \sum_{k=0}^{\infty} u^k \left\{(1+c)y_k \left(1 - h_k \frac{1-q_k}{1-p_k-q_k}\right) - y_k\right\}$$

- If the ratio of PC p_k is big enough, then MM has more fitness than PC.
- This is reasonable because the higher proportion of PC, the more ability of access to cuckload by MM.
- Also, the higher ratio of MG q_k, the more fitness of PC. It is also possible because the former restrict the number of MM.

Analysis

- $W_p - W_G = \sum_{k=0}^{\infty}\left[u^k y_k\left\{(1-h_k)(1+c) - \frac{1}{1-u}\prod_{j=1}^{k-1}(1-y_j)\right\}\right] - \frac{y_0}{1-u}$

$\approx \frac{y_\infty\left((1+c)(1-h_\infty) - \frac{1}{1-up}\right)}{1-u} - \frac{y_0}{1-u} \approx \frac{y_\infty\left(c(1-h_\infty) - \frac{1}{1-up} - h_\infty\right)}{1-u}$ (if we set $y_0 \approx y_\infty$)

- Also, if the men's survival rate u is high, then the MG's fitness is higher than PC.
- But in ancient, we can expect u is low enough, so this is why many theory think that monogamy is derived from PC.

Analysis

- $W_m - W_G = \sum_{k=0}^{\infty} u^k \left(y_k \left(1 - \prod_{j=1}^{k-1} (1 - y_j)\right) + (1+c) h_k \frac{y_k p_k}{1 - p_k - q_k} \right) - \frac{y_0}{1-u}$

$$\approx \frac{y_\infty \left(1 + (1+c) h_\infty \frac{p_\infty}{1 - p_\infty - q_\infty}\right) - y_0}{1-u} - \frac{1}{1-up}$$

$$\approx \frac{y_\infty \left((1+c) h_\infty \frac{p_\infty}{1 - p_\infty - q_\infty}\right)}{1-u} - \frac{1}{1-up} \text{(if we set } y_0 \approx y_\infty\text{)}$$

- It means that if PC is extinct by MM, then fitness of MG is higher than MM. It is same result of comparison between PC and MM.

Conclusion

- Canela people in Brazil, Acehnese people in Indonesia and Bari people in Venezuela allow Multiple Mating until 1970s, when the survival rate began to increase(EBS Docuprime, sex #003).
- This means that the model in paper is well-made.
- Fitness function of one stragy get effect from others, which means that there is a game between players whose stragy are different.
- But the bifurcation does not need because not only complexity but also organism does not think it carefully.

Other Possible story

- What if Male Guarding is not perfect?
- If do, then fitness of MM and MG is like below.
- $W_m = \sum_{k=0}^{\infty} u^k (y_k + (1+c)\, h_k \frac{y_k p_k}{1-p_k-q_k} + \frac{y_k q_k r}{1-p_k-q_k})$
- $W_G = \frac{y_0(1-r)}{1-u} + \sum_{k=1}^{\infty} \frac{u^k y_k}{1-u} \prod_{j=1}^{k-1}(1-y_j)(1-r)$
- $\frac{y_k q_k r}{1-p_k-q_k}$ is benefits by cuckload to MG and r is a probability of successful cuckload to MG.

Reference

- Schacht, R., Bell, A. The evolution of monogamy in response to partner scarcity. *Sci Rep* **6**, 32472 (2016). https://doi.org/10.1038/srep32472